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Pennsylvanian Sediment - Fossil Relationships in Part of the Black Warrior Basin of Alabama.

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PENNSYLVANIAN SEDIMENT-FOSSIL RELATIONSHIPS IN PART OF THE BLACK WARRIOR BASIN OF ALABAMA

A Dissertation

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in

The Department of Geology

by
James Walker McKee
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". . . in science, presumption is less hurtful than despair, and inactivity is more dangerous than error."

Playfair

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ABSTRACT

Many exposures of fossiliferous Pennsylvanian rocks of the Black Warrior Basin in Alabama show evidence that the fossils they contain are surrounded by the same sediments which surrounded them or supported them in life; therefore they provide an opportunity to study the relationships between fossil animals and fossil substrates--relationships which are useful in paleoecological interpretations.

Sampling yielded data useful in demonstrating that the rocks under study are not homogeneous with respect to certain variables of fossil occurrence, and that these variations are related to sediment properties. Maximum (but not minimum) mean grain size was found to be a limiting factor in the occurrence of fossils; of the fossiliferous rocks, the coarser-grained ones and those with the higher proportion of grains to matrix contain fossils in greater density; at least one taxon acts as an indicator of fossil density; some taxa occur in positive association, others in negative association; some taxa show preference for certain conditions of grain size and percentage, and for certain inferred conditions of Eh and pH.

These relationships lead to hypotheses regarding the habitat and mode of life of some taxa.

INTRODUCTION

Aside from considerations of preservation and preservability, the occurrence of a particular fossil at a particular place is controlled by time (or stage of evolution), barriers to migration, and paleoenvironments. The first of these has been the subject of the greatest amount of research effort, for it is the control of occurrence by time that has enabled stratigraphers to determine the relative chronologic positions of the layers of the earth's crust. Environments, however, can exert just as positive control over occurrence--a fact of considerable inconvenience to stratigraphic paleontology. Since this is the case, and since knowledge of past environments and ecology is interesting in itself, there has been an increased amount of research activity in paleoecology in recent years. Unfortunately, the actual knowledge of paleoecology does not seem to have increased in proportion to the research effort applied. The reason for this is well stated by Krumbein and Sloss (1963): ". . . In attempting refinement of ecologic detail, two major stumbling blocks are encountered. The . . . living community, is only partly preserved and is confused by extraneous admixtures, whereas the physical elements of the environment are not buried with the fossils."

Although it is true that most elements of the physical environment are not buried with the fossils, at least one may be. In some fossiliferous rocks, the same sediments which surrounded or supported the organisms in life are apparently still present. Such sediments are certainly elements of the physical environment, and variations in their characteristics may well be related to variations in the occurrence of fossils. The sediments in most fossiliferous rocks are probably not precisely the ones on or in which the organisms lived, or, if they are, offer little direct evidence of the relationship.

The moderately fossiliferous Pennsylvanian rocks of the Pottsville Formation in the Black Warrior Basin of Alabama afford an unusual opportunity for a study of the relationship between fossils and the surrounding sediments because in many places, there is evidence that the fossils were buried in the same place (and, frequently in the same position) in which they lived. For example, Aviculopinna is generally found in a vertical position; productoids commonly have their long spine intact; and fossils concentrated in thin, highly fossiliferous beds usually do not have the aspect of transported shells but, rather, appear to represent buried horizons of particularly abundant life.

In general, the Black Warrior Basin was characterized in Pennsylvanian time by rapid deposition and concomitant rapid changes in environment. The general setting was such that no large-scale geological phenomena were required to produce significant environmental changes. These changes may have been partly due to slight fluctuations in sea level which permitted periodic influx of salty and brackish water over the low lands. However, much of the area was probably subjected to considerable variations in water level and salinity due to more commonplace causes such as variations in run-off. Or, changes of water flow (stream and tide) may have been caused by plant growth or by changing patterns of deposition, such as might result from the shifting of stream channels. That the organisms responded to these rapid changes in environment is clear, both from observation in the field, and from evidence presented here as to the selectivity of fossils with respect to rock characteristics--which reflect at least some aspects of the physical environment.

In the area under study, there is an interaction between rock properties and fossil variables, and the area is heterogeneous with respect to fossil density and with respect to the occurrence of fossil taxa. This statement was confirmed by testing a series of hypotheses, the results of which also carried information which was useful in postulating details of the habitat requirements and mode of life of some of the taxa which were encountered during sampling. The hypotheses are:

1. The presence or absence of fossils is related to sediment properties
2. Fossil density varies with sediment properties
3. The occurrence of particular taxa is related to sediment properties
4. Fossil density varies with the occurrence of particular taxa
5. Certain fossils of different taxa tend to occur together
6. Certain fossils of different taxa tend not to occur together.

The outcrops which were selected for this study are shown on the map, Figure 1. The approximate stratigraphic position of the sample localities is shown in Figure 2.

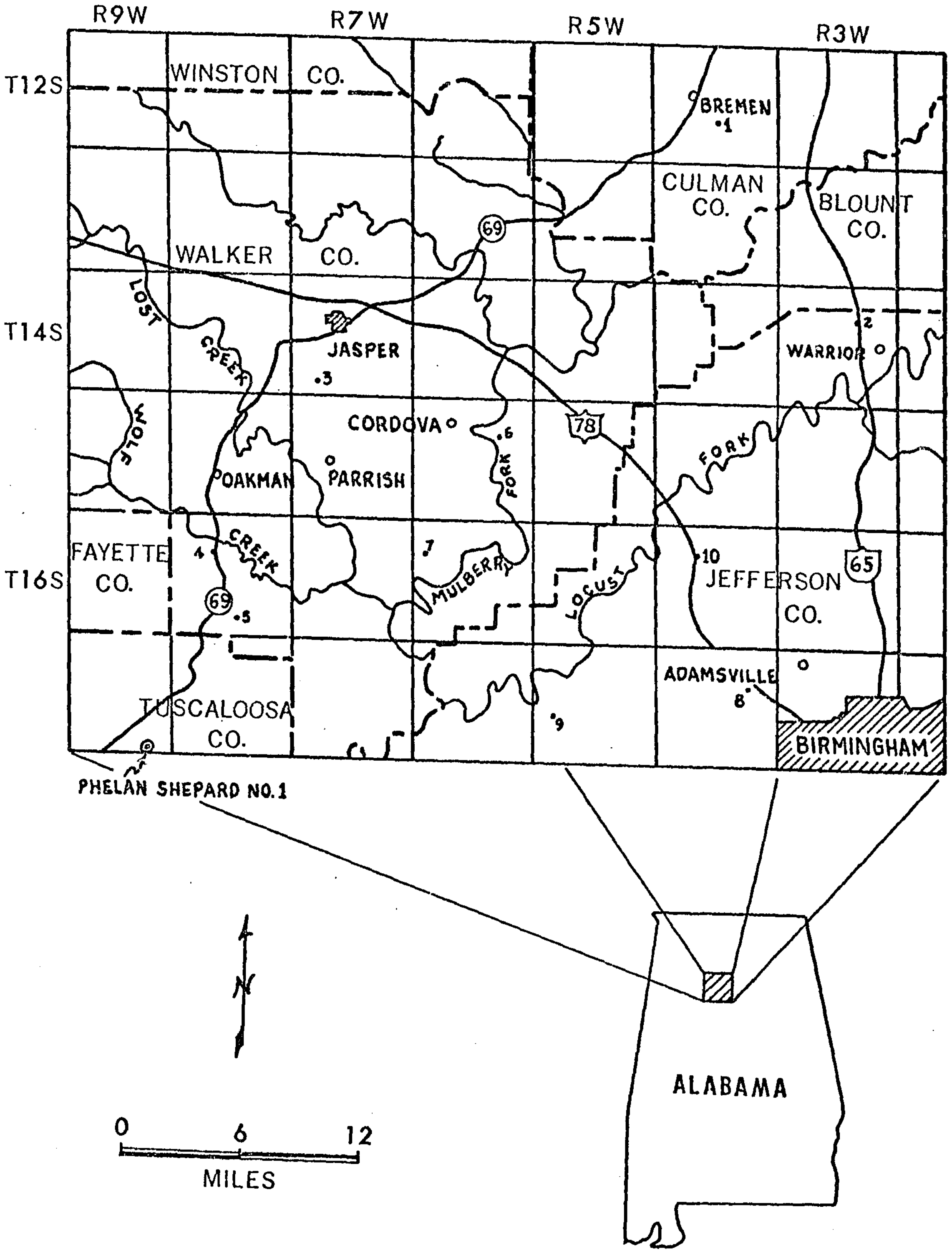
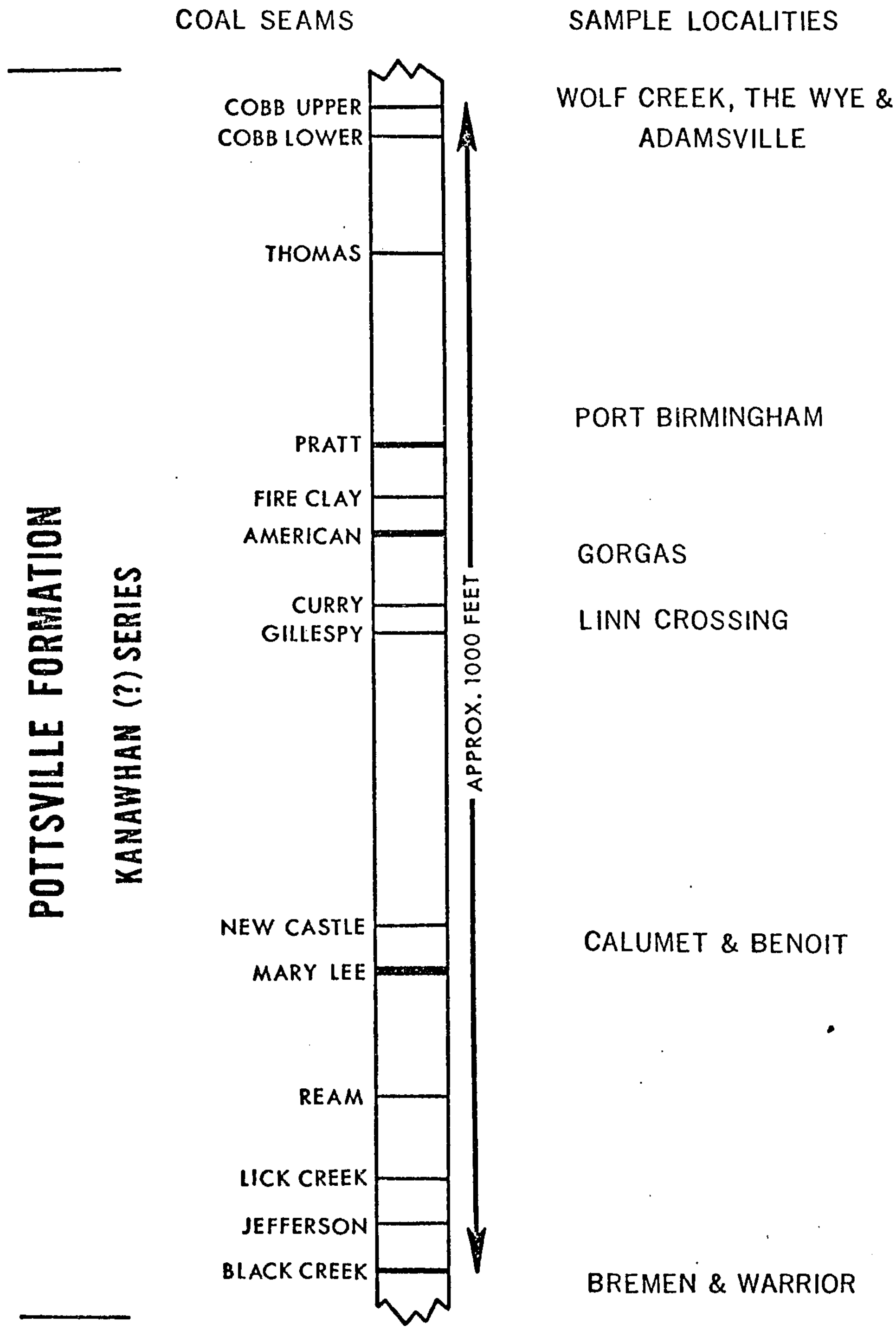


FIGURE 1

LOCATION MAP

FIGURE 2

APPROXIMATE STRATIGRAPHIC POSITION OF SAMPLE LOCALITIES



COLUMN FROM MC CALLEY 1898

SAMPLING

General Requirements

The sampling plan was devised to yield data which are informative with respect to 1) the characteristics of the matrix (sediment) in which the fossils are preserved, 2) the taxa present within a type of matrix, 3) the associations of fossils within a matrix type, and 4) intertaxon and intrataxon density. Three requirements determined the nature of the sampling unit. It must not span rock types; all points within it must be virtually synchronous; and the technique must be workable in all types of rock. The first two requirements limited the unit to a plane or a line oriented parallel to bedding. The third requirement indicated that a line rather than a plane be used because of the difficulty of exposing a bedding plane in massive, well-indurated rocks. The length of the sampling line or unit was rather arbitrarily set at one meter. This is short enough so that if arranged parallel to bedding, all points along it can be assumed synchronous. It is long enough that the likelihood of its intersecting a fossil is not too remote in rocks of moderate fossil density. In addition, it is conveniently divided into one hundred equal parts.

Method

Ten suitable outcrops were selected. Any outcrop was judged suitable if it was not badly weathered and if it contained fossils which did not show evidence of having been transported. Two to ten random points were located on each of the ten outcrops. The number of points was governed by the apparent fossil density, the size of the outcrop, and the lithologic and faunal homogeneity of the outcrop. There were 67 such points in all. The macro fossil nearest to each of these points was located and a sample line was constructed through this fossil, which was placed at the 50 centimeter point of the one-meter sample line. This insured that there be at least one fossil per sample line. Every other macrofossil intersected by the line was collected, along with a small quantity of the sediment immediately surrounding it, and the centimeter point at which it intersected the line was recorded.

Evaluation

Table I summarizes the nature of the data which this procedure yielded. Although this sampling plan seems to be the one best suited to the rocks of the Black Warrior Basin and to the nature of the problem, it does not yield completely unbiased data. Variations in size of fossils influence the likelihood of their being intersected by the sampling line. This is important when number of fossils rather than volume is the information being sought. Shape and living position also introduce bias, for a large pectenacean preserved in its living position offers a smaller target for the sample line than does an *Aviculopinna* of roughly equivalent size. Bias can also be introduced between sample lines in different rock types. If specimens in a shaly rock are somewhat flattened, then they are less likely to be

TABLE I

NATURE OF DATA YIELDED BY SAMPLING

Type of Data	Informative with Respect to:
Number of fossils on a line.	Intertaxon density
Taxa	Associations of taxa and taxa present
Number of taxa	Diversity
Number of fossils within a taxon . . .	Intrataxon density
Distance between specimens	Intertaxon density
Distance between specimens of a taxon.	Intrataxon density
Sediment	Sediment characteristics

intersected by the sample line, and the result would be a comparatively lower fossil density indicated for the shale. The fact that specimens are somewhat easier to locate in a shale causes a compensating error. Another drawback to this sampling method (but an unavoidable one) is that no choice is given as to which specimens to collect. Therefore, many are poorly preserved, and many others are broken in the process of being removed from the rock.

THE ROCKS

General

The rocks of the Black Warrior Basin consist of low-rank graywackes, associated dark shales, a small percentage of bedded and nodular clay ironstone, and coal. The total thickness of the section is probably about 5000 feet. The lithology of the Basin has been described by Ehrlich (1965), who demonstrated that the detritus probably came from a southern source. The sediments were deposited in deltaic, fluvial, and marine environments. Plant fossils are abundant, and many exposures contain at least some evidence of animal life, provided a sufficiently diligent search is made. Rapid subsidence and concomitant accumulation of sediments are evidenced by the thickness and composition of the deposit, the presence of long tree trunks fossilized in a vertical position, and the high percentage of shellfish which were preserved in their life position due to rapid burial. Because of rapid deposition and the complex of environments which must have existed at a given time, the lateral continuity of individual rock bodies is short. Consequently, the detailed lithostratigraphy of these rocks has not yet been worked out. Subdivision on the basis of marker horizons, i.e., coal beds, was made many years ago, and these markers remain the best indicators of stratigraphic position (Figure 2).

Localities Sampled (Figure 1)

Locality 1, Bremen: N 1/2, SW 1/4, Sec. 22, T. 12 S., R. 4W., Cullman Co., Ala. Exposure high above road on north side. Only the uppermost part was sampled. Fossils abundant and diversified. An apparently homogeneous siltstone, somewhat more weathered than the other localities.

Locality 2, Warrior: E 1/2, SW 1/4, Sec. 11, T. 14S., R. 3 W., Jefferson Co., Ala. Exposure on west side of U. S. 78, which now bypasses the town of Warrior. Vertical variations in lithology and faunal composition frequent and abrupt. Contains siltstone, sandstone, shale, and some clay ironstone.

Locality 3, Calumet: SE 1/4, NW 1/4, Sec. 32, T. 14 S., R. 7 W., Walker Co., Ala. Railroad cut, southeast side of tracks. Mostly massive siltstone with fossiliferous bands 15 or 20 feet above tracks.

Locality 4, Wolf Creek: NW 1/4, SW 1/4, Sec. 9, T. 16 S., R. 8 W., Walker Co., Ala. Black shale on western side of Alabama Highway 69.

Locality 5, The Wye: NE 1/4, NW 1/4, Sec. 34, T. 16 S., R. 8 W., Walker Co., Ala. Exposure of black shale on north side (inside) of wide bend in road 0.4 mile southeast of The Wye. (The position of this road has been changed since the 1955 edition of the Tutwiler School quadrangle.)

Locality 6, Benoit: NE 1/4, SW 1/4, Sec. 11, T. 15 S., R. 6 W., Walker Co., Ala. A shale unit with many layers of clay ironstone, exposed at crest of ridge. (Road has been straightened since 1951 edition of Cordova quadrangle.)

Locality 7, Gorgas: SE 1/4, Sec. 7, T. 16 S., R. 6 W., Walker Co., Ala. Exposure on north side of highway, about 1.2 miles west of Copeland Ferry Bridge. Mostly a massive siltstone banded with stains of iron oxide, apparently from weathering of siderite cement. Lower, unfossiliferous portion of outcrop with same appearance as upper fossiliferous portion, except for subtle color difference.

Locality 8, Adamsville: W 1/2, SE 1/4, Sec. 11, T. 17 S., R. 4 W., Jefferson Co., Ala. Sparsely fossiliferous siltstone on east side of highway, just west of Crumley Chapel.

Locality 9, Port Birmingham: NE 1/4, Sec. 19, T. 17 S., R. 5 W., Jefferson Co., Ala. Exposure of black shale with nodular clay ironstone on north side of Birmingport Road near crest of first hill southeast of road junction at Short Creek.

Locality 10, Linn Crossing: E 1/2, NE 1/4, Sec. 8, T. 16 S., R. 4 W., Jefferson Co., Ala. Exposure of black shale with tabular clay ironstone on east side of Bankhead Highway a few feet above thin coal exposed in ditch. Very sparsely fossiliferous.

Grain Size and Percent Grains

Examination under a stereoscopic microscope revealed no discernible difference between rock samples taken from along any sample line, so only one rock specimen per sample line was thin sectioned. The ratio of grains (usually quartz in these rocks) to matrix[1] was

[1]The terms grain and matrix are used in the sense described by Krynine, 1948, pp. 137, 138.

determined by the point count method (Chayes, 1949). Twenty-five points were counted in each thin section. This was done at a relatively low magnification in order to reduce the tendency to count all quartz particles as grains, for the percentage of quartz was not the information sought. The size of the grains in the sediments of each sampling unit was estimated by measuring the apparent long axis of ten grains in each thin section. These data (percentage of grains and size of grains) were then plotted on a coordinate system (Figure 3, Table II).

The percentage of matrix, i.e., the proportion of a sample, the particles of which are less than a certain relative size, is an indicator of overall particle size. Grain size is also an indicator of overall particle size. By partitioning a best-fit line such as the one in Figure 3, a single measure of overall particle size could be formed, and the occurrence of fossils compared to this. But since some taxa were found to respond to one of these statistics and not to the other, it was thought best to consider them separately. On the assumption that a wide range of detrital particle sizes were available for transportation and deposition, grain percentage would seem to be a reflection of the duration of comparatively strong water movement, and grain size would reflect the strength of movement. Strength and duration of water movement might elicit different responses from different taxa.

Color

One sediment sample from each sample line was powdered in a

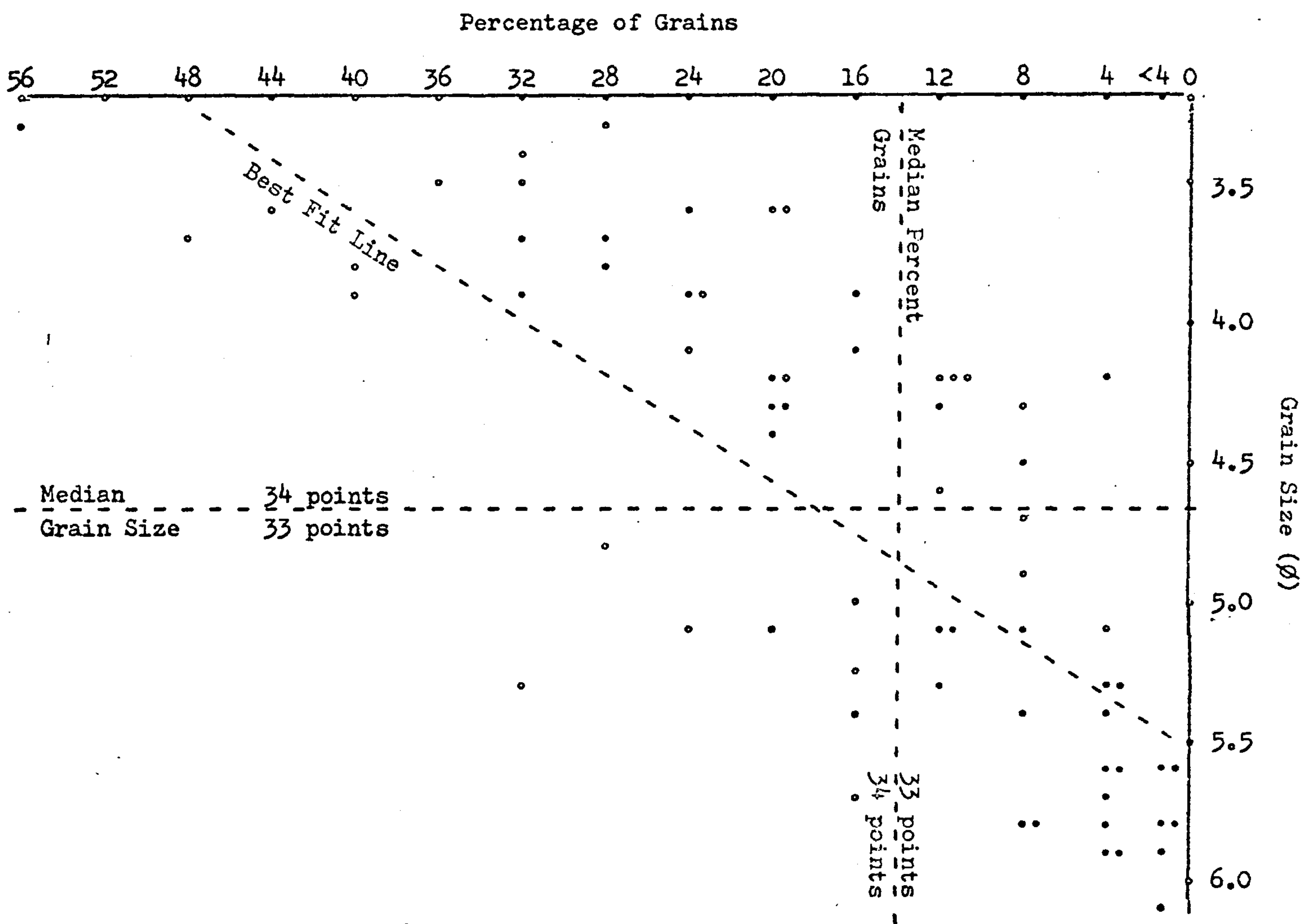


FIGURE 3

SEDIMENT SAMPLES BY MEAN GRAIN SIZE (Ø)
AND PERCENTAGE OF GRAINS

TABLE II

ROCK SAMPLE DATA

Mean Grain Size--Percent Grains--Color

Sample Number	$\bar{X}_\phi$	Percent Grains	Color Category	Sample Number	$\bar{X}_\phi$	Percent Grains	Color Category
011	3.85	16	4	061	5.23	16	3
012	4.50	8	5	062	5.37	4	3
013	4.76	28	5	063	5.38	8	2
014	4.63	12	4	064	5.07	12	1
015	4.43	20	5	065	5.33	4	3
021	3.68	48	4	071	3.67	32	1
022	3.91	40	5	072	3.81	40	4
023	3.93	24	2	073	3.29	56	5
024	3.65	28	5	074	3.83	28	1
025	4.08	24	1	075	4.25	20	4
026	4.18	12	2	076	4.17	20	4
027	4.32	12	2	077	3.59	20	1
028	4.32	20	2	078	3.58	44	4
029	4.23	20	4	079	3.90	32	1
0210	4.16	12	4	0710	3.48	36	1
031	3.47	32	4	081	4.22	4	4
032	3.92	24	5	082	4.26	8	2
033	4.72	8	2	083	4.18	12	2
034	3.43	32	2	084	4.11	16	2
035	3.62	24	2				
036	3.30	28	1	091	5.61	<4	3
037	3.58	20	4	092	5.92	<4	5
				093	6.07	<4	3
041	4.89	8	2	094	5.62	<4	3
042	5.03	16	4	095	5.70	4	2
043	5.28	12	2	096	5.83	<4	3
044	5.07	24	2	097	5.83	4	5
045	5.11	12	2	098	5.92	4	3
046	5.07	8	2	099	5.85	4	5
047	5.41	16	5				
048	5.63	4	4	101	5.76	<4	3
				102	5.60	4	4
051	5.80	8	2				
052	5.11	4	5				
053	5.79	8	3				
054	5.25	32	5				
055	5.74	16	5				
056	5.25	4	5				
057	5.07	20	5				

WIG-L-BUG (Crescent Dental Manufacturing Company, Chicago, Illinois). The powder was placed in small glass vials, then arranged by subtle color differences into five categories: 1, yellow-gray; 2, darker yellow-gray; 3, yellow; 4, gray; 5, darker gray.

Thin section examination showed altered siderite to be the mineral responsible for the yellow tints. Some of the minute siderite crystals have altered to a brown or orange color, but are still translucent. This type of alteration has been described by Kerr (1959). Other siderite, sometimes in the same thin section with the colored, translucent variety, has altered to iron oxide, apparently limonite. Only a minute amount of this altered siderite of either or both varieties is necessary to provide the powdered specimens with a discernable yellow tint. "Yellow tint" may, then, be translated to "contains siderite." Grain size and percentage of grains are indicative of the amount of quartz present, which, when powdered, provides a neutral base, and for a given amount of altered siderite, would be expected to lighten the color. Iron sulfide and organic matter have the reverse effect, and either darken the yellow or mask it altogether. Specimens which are low in siderite and comparatively high in iron sulfide and organic material are those of the gray categories. The primary coloring agents (altered siderite, iron sulfide, and organic matter) may all occur in small quantity scattered through the same thin section. The siderite, however, may increase in amount until it is one of the major constituents, as in a clay ironstone concretion or bed. These specimens are a pronounced yellow, and are therefore placed in category 3.

Figure 4 shows the relationship between color categories and grain size. In the yellow categories (1 through 3) the color of the powdered specimen deepens as the original grain size decreases. In the pure gray categories (4 and 5) there is no such pronounced affect. These apparent responses by color to grain size are verified by the cumulative binomial distribution. A total of eight samples was placed in color category 1. Of these, only one was from a sediment with less than the median grain size. The hypothesis that there is an equal probability that the color specimens fall above as below the grain-size median must be rejected, for the probability, under these conditions, of there being one or fewer below the median is .035. This is shown in Table III together with the same information for the other four color categories. Figure 5 shows that there is a relationship between color categories and the percentage of grains in a specimen. As the color of the powdered specimens deepens in the three yellow-tinted categories, the original percentage of grains decreases. In the pure gray categories, there seems to be no difference in grain percentage (Table IV).

The occasional occurrence of siderite and pyrite in the same thin section raises a question as to the mode and time of origin of the siderite, for siderite and pyrite are on different sides of the sulfate-sulfide fence (Krumbein and Garrels, 1952). There seem to be two possibilities. (1) The siderite may have formed on or near the sedimentary interface, where the effective Eh was high enough to permit its formation, while pyrite was forming somewhat farther beneath the

FIGURE 4

GRAIN SIZES FOR EACH COLOR CATEGORY

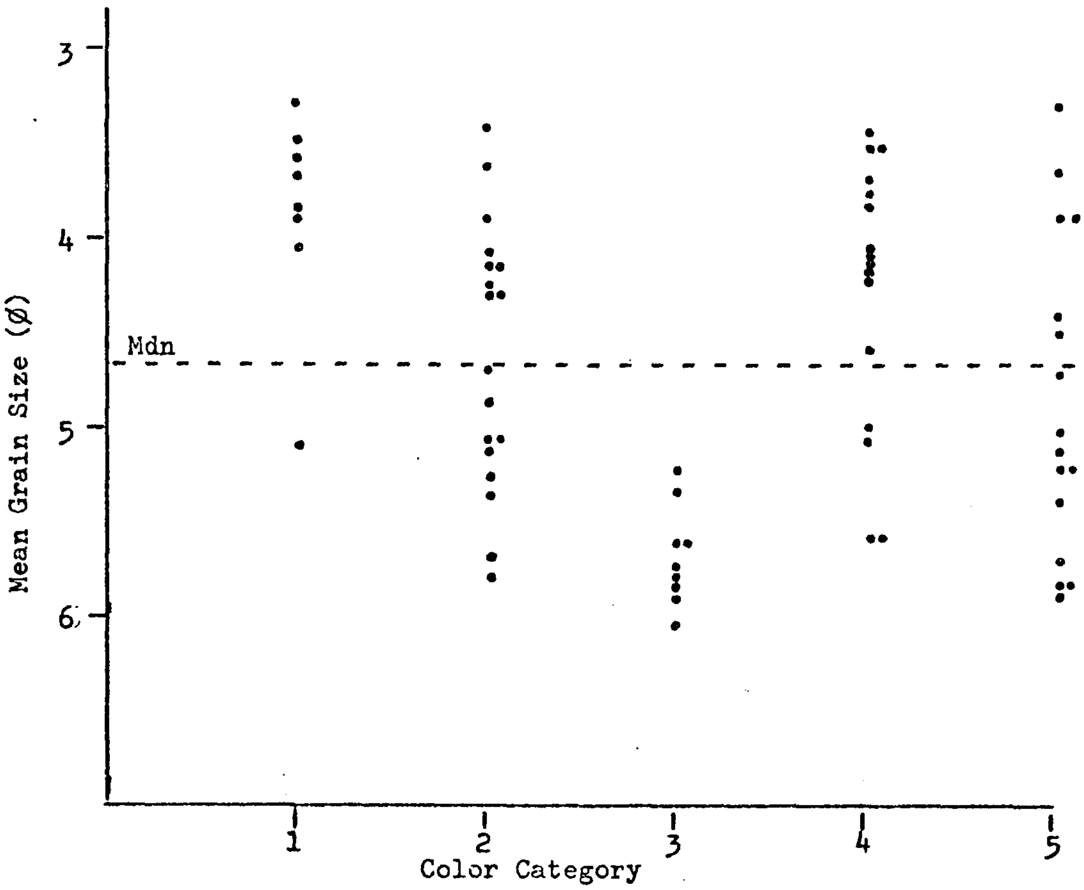


FIGURE 5

GRAIN PERCENTAGES FOR EACH COLOR CATEGORY

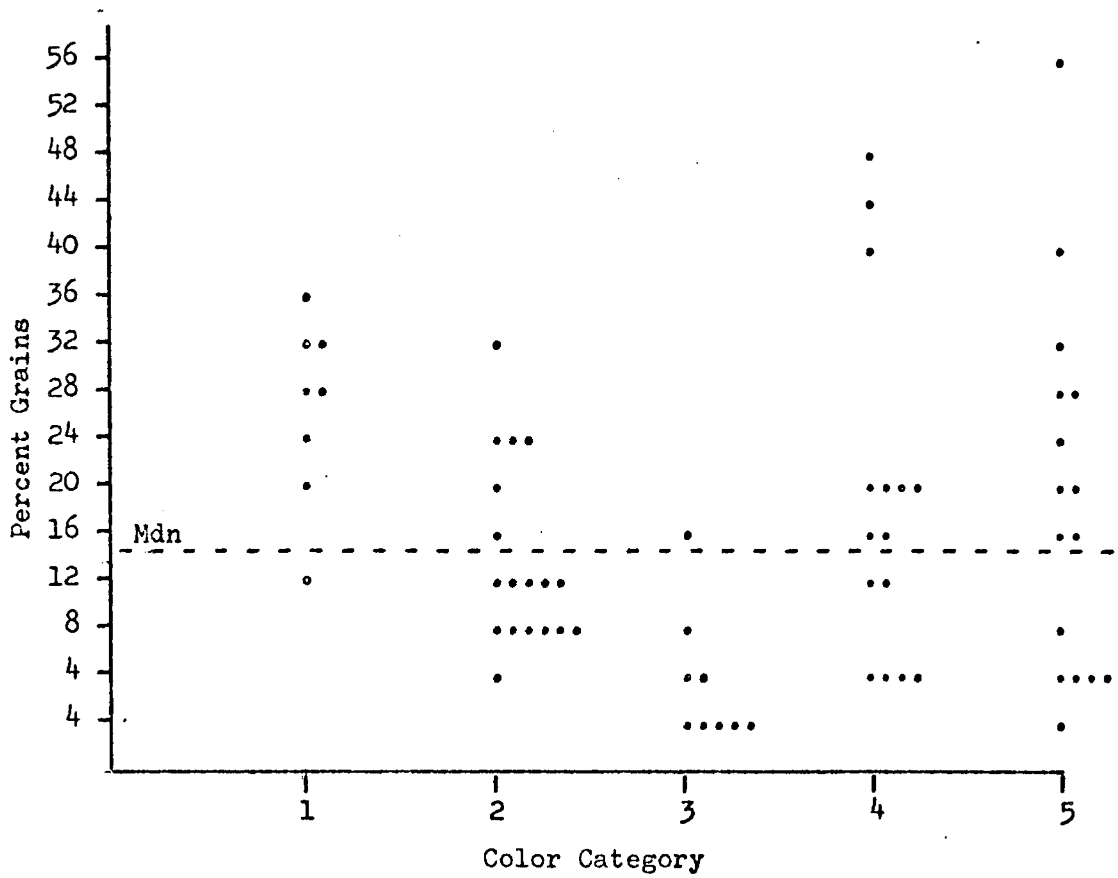


TABLE III

DISTRIBUTION OF COLOR-CATEGORIZED SAMPLES WITH RESPECT TO MEDIAN GRAIN SIZE

Color Category	1	2	3	4	5
No. of Samples above Median	7	9	0	12	6
No. of Samples below Median	1	9	9	4	10
Significance	yes	no	yes	yes	no
Probability of this distribution or one of greater imbalance occurring, on assumption that true probability of occurrence above or below median is 0.5	.035	.593	.002	.038	.227

TABLE IV

DISTRIBUTION OF COLOR-CATEGORIZED SAMPLES WITH RESPECT TO MEDIAN GRAIN PERCENTAGE

Color Category	1	2	3	4	5
No. of Samples above Median	7	6	1	10	10
No. of Samples below Median	1	12	8	6	6
Significance	yes	no	yes	no	no
Probability of this distribution or one of greater imbalance occurring, on assumption that true probability of occurrence above or below median is 0.5	.035	.119	.019	.227	.227

interface, where the Eh was lower. In some cases, pyrite may have formed at or near the interface in local situations where animal tissues were cut off from contact with the surrounding interstitial fluid by the shell of the animal--as in the center of a productoid spine. In such a case, the general Eh-pH conditions are irrelevant, for the necessary conditions were provided by the microenvironment within the spine. (2) The siderite may have formed at a considerably later time than the pyrite, from carbonate contained in the shells of the fossils. This appears to be the less likely possibility, however, because there is no significant relationship between color (siderite) and fossil density (availability of calcium carbonate).

Yellow color appears to be a reflection not of the degree of weathering, but of the amount of siderite present. The category "yellow" changes with grain size and grain percentage, and there is no reason to assume that the intensity of weathering would change in the same way, that is, that it would be greater in the finer-grained rocks. Furthermore, none of the samples from the Bremen locality, which appears to have undergone more weathering than the others, is of yellow tint because those samples are low in siderite. The Benoit locality was also somewhat weathered. All samples from there were in yellow categories, but ironstone (clayey iron carbonate) can be seen there in considerable abundance.

Fossiliferous and Non-fossiliferous Rocks

General Observations

Well stratified rocks with original bedding preserved are almost exclusively non-fossiliferous in the study area. Exceptions are rare, and when they occur, the fauna is sparse. This relationship is expected, for much animal activity is certain to disrupt whatever structures may have been formed by the sedimentary processes.

Rocks of "coarser" grain sizes, that is, fine sand and larger, are rarely fossiliferous. Exceptions occur generally at the top of a sandstone body where the presence of fossils perhaps reflects the onset of conditions which were to result in the deposition of finer sediments and invasion by preservable organisms in wider variety and greater number.

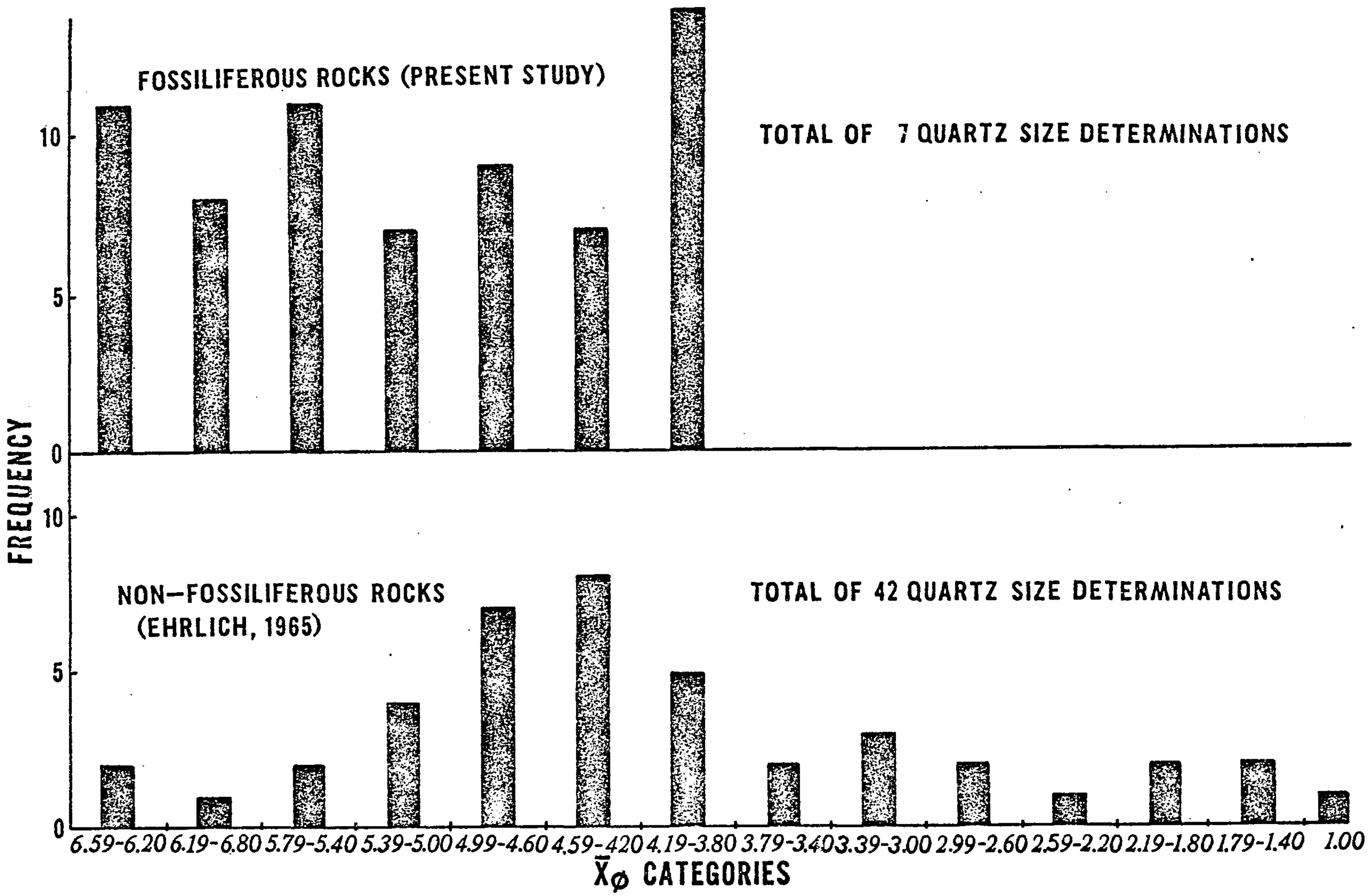
Shales with tabular clay ironstones are generally non-fossiliferous. The only observed exception is at Locality 10, near Linn Crossing, which contains a few specimens of *Orbiculoidea*. The reason for the scarcity of fossils in such shales may be that tabular clay ironstone indicates fresh water deposition. (Plant remains are frequently found in shales containing such clay ironstones.) Or, it may simply be that had many animals been present, their activity would have prohibited the formation of the clay ironstone as thin sheets of comparatively even thickness, but permitted its formation in some other, less even pattern.

Comparison with Core Data

In order to compare the characteristics of the fossiliferous rocks included in the present study with the non-fossiliferous rocks in the Black Warrior Basin (which were not included in the sampling), data gathered by Ehrlich (1965) were used. Ehrlich's study included examination of a 3200-foot core taken on Wiley Dome by the Southern Natural Gas Company (Phelan-Shephard no. 1, SE 1/4, SE 1/4, Sec. 35, T. 17 S., R. 9 W., Tuscaloosa Co., Ala.). Ehrlich's samples were taken at random, except that fossiliferous zones, or zones in which bedding was disturbed, (by animal activity?) were avoided. Since Ehrlich measured the apparent long axis of random quartz particles, his data are not directly comparable to the grain size data collected for this study, for a few of the quartz particles are sufficiently small that they are a part of the matrix. There are enough of these to cause slightly different results. In order to permit direct comparison of the two sets of samples, quartz particle size estimates were made for each of the 67 specimens of fossiliferous rock. Comparison of those of Ehrlich's data from the same stratigraphic interval as the samples in the present study with the data on fossiliferous rocks shows that the fossiliferous rocks span a narrower range of quartz sizes than do the non-fossiliferous rocks (Figure 6). This would seem to indicate that the kinds of animals studied exercised habitat selection with respect to quartz size (which approximates grain size) of the substrate--or at least that quartz size and animal occurrence both reflect some other factor or factors.

FIGURE 6

QUARTZ PARTICLE SIZES OF FOSSILIFEROUS AND NON-FOSSILIFEROUS ROCKS



THE FOSSILS

Fossil Taxa

Selection of taxonomic levels for categorizing the fossils taken in the sampling program involved several considerations. First, the application of some of the statistical procedures required a reasonably large number of specimens per taxon. Second, fine distinctions between taxa, especially at the species level, would sometimes be difficult or impossible to make because of fragmentation of some during collecting, and poor preservation of others. Third, fine distinctions would introduce the possibility of evolutionary and environmental changes in morphotype.

All the identifiable taxa which occurred on the sample line are shown in Table V. The following ten taxa (marked with asterisks in Table V), eight of the generic level and two of essentially class level, were used in the analyses: *Dunbarella*, *Aviculopinna*, *Linoproductus*, *Echinoconchus*, *Antiquatonia*, *Desmoinesia*, *Lissochonetes*, *Schizophoria*, gastropods, and clams (i.e., pelecypods except *Dunbarella* and *Aviculopinna*).

Associations of Fossils

Two or more taxa are associated if they occur in the same sample line more often than would be expected by chance.

In determining associations, all possible combinations of taxa were examined. All but ten of these were rejected on inspection

TABLE V

OCCURRENCE OF TAXA BY SAMPLE UNIT

Locality Name and Number	Sample Line Number	TAXA										gastro-pods*				clams*										Totals by Locality	Not in Table	Tot. Specimens/Loc.
		Echinoconchus*	Linoproductus*	Antiquatonia*	Desmoinesia*	Lissochonetes*	Schizophoria*	Spiriferidina	Derbyia	Orbiculoidea	Bellerophon	Euphemites	Trepospira	Ianthinopsis	Worthenia	Astartella	Edmondia	Dunbarella*	Aviculopinna sp.*	Aviculopinna para	Michelinoceras s.l.	coral	echinoid	crinoid columnal	Calamites			
Bremen 01	1					2						1														3	5	8
	2		1											1							1					4	1	5
	3					1							1													2	1	3
	4					1							1		1	1										4	1	5
	5						2						1													3		3
Warrior 02	1		1	1	1	1	3	1								1							1	1		11	1	12
	2					2					1								2							4	1	5
	3	4	8																							12	2	14
	4					2	1									1						1				5	1	6
	5	6	21																							27		27
	6		7																							7		7
	7		1																							1	1	2
	8	1	2																							3	1	4
	9		2																							2		2
	10											1					1									2		2
Calumet 03	1				2																					2	1	3
	2																						1			1		1
	3												1													1		1
	4				4														1							5		5
	5				5																					5		5
	6				1																					1		1
	7				1																					1		1
Wolf Creek 04	1					2																				2		2
	2					4																				4	1	5
	3					1																				1		1
	4					3																				3		3
	5					3																				3		3
	6					2																				2		2
	7					9																				9		9
	8					3																				3		3
The Wye 05	1					2		1																		3		3
	2				2	1																				3		3
	3					1													1							2		2
	4				1	6																				7		7
	5					3																				3		3
	6					1																				1		1
	7				2	2																				4		4

TABLE V (continued)

Locality Name and Number	Sample Line Number	Echinoconchus*	Linoproductus*	Antiquatonia*	Dêsmoinesia*	Lissochonetes*	Schizophoria*	Spiriferidinian	Derbyia	Orbiculoidea	Bellerophon (gastropods*)	Euphemites (gastropods*)	Trepospira (gastropods*)	Ianthinopsis (gastropods*)	Worthenia (gastropods*)	Astartella (clams*)	Edmondia (clams*)	Dunbarella*	Aviculopinna sp.*	Aviculopinna para	Michelinoceras s.l.	coral	echinoid	crinoid columnal	Calamites	Totals by Locality	Not in Table	Tot. Specimens/Loc.
	1		3	4																						7	2	9
	2	1	2	3																						6	1	7
Benoit	3		1																							1		1
06	4	2	1	3																						6		6
	5		1	9																1						11	3	14
	1			1																1						4		4
	2								1																	1		1
	3						1																			1		1
Gorgas	4			1					1											1						3		3
07	5																			1						1		1
	6						3													1						4	1	5
	7																									1		1
	8									1										1						1		1
	9						2																			3	2	5
	10		1																							1	1	1
	1																							2		2		2
Adamsville	2	1																1								2		2
08	3			1																						1	2	3
	4								1																	1		1
	1																	1								1		1
	2																1	2								3		3
	3																	2								2		2
	4					1																			1	2		2
Port	5																	2								2		2
Birmingham	6																	2								2		2
09	7																	1								1		1
	8																1	1								2		2
	9																	1								1		1
Linn Cross-	1									1																1		1
ing 10	2									1																1		1
																										231		260

because the number of sample lines on which they occurred was too small to be meaningful, or because the members of the pair did not occur together at all. The ten candidate pairs were tested for association in 2X2 contingency tables. The taxa found to be involved in significant associations were as follows:

Linoproductus

.01 .01

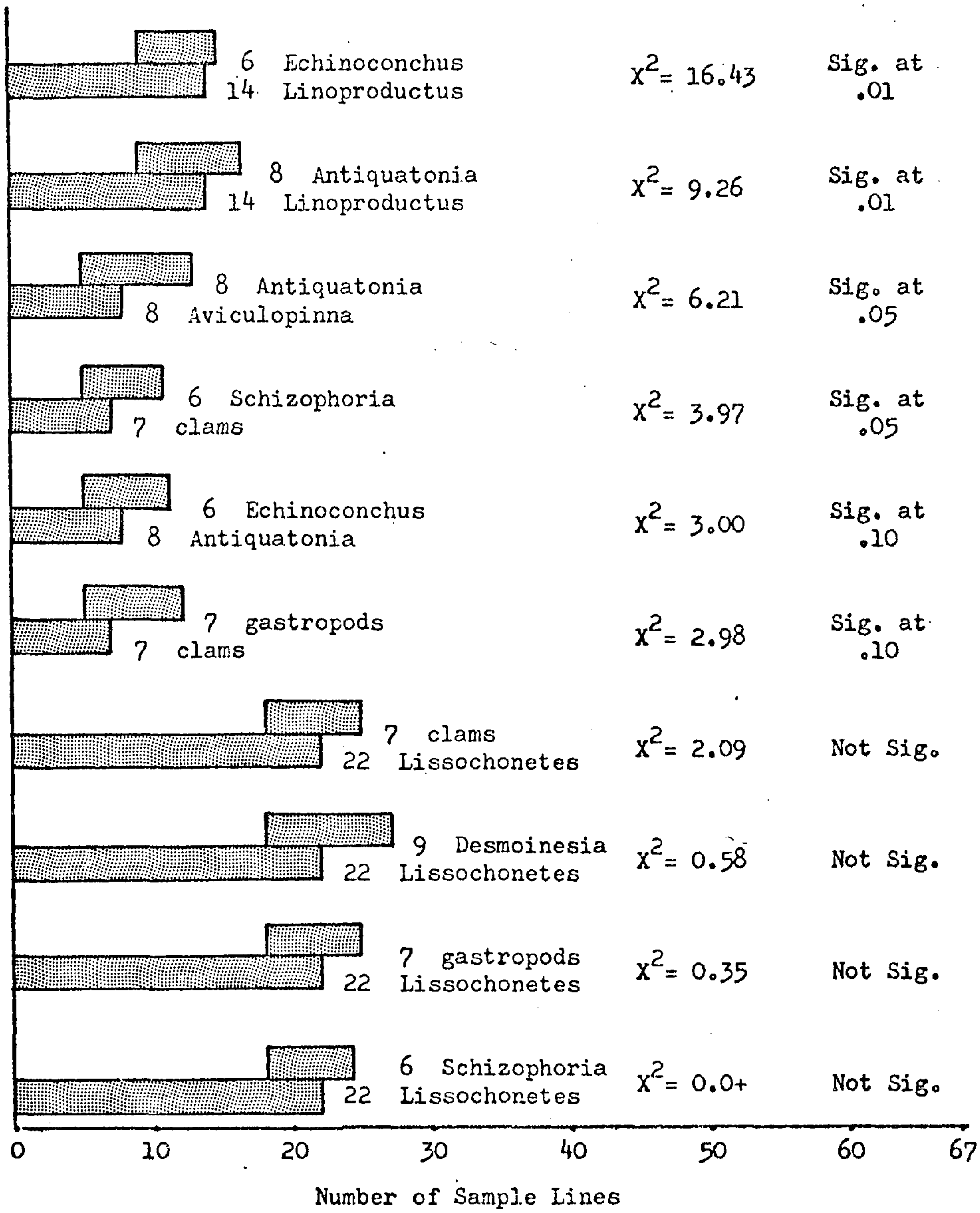
Echinoconchus —— .10 —— *Antiquatonia* —— .05 —— *Aviculopinna*

gastropods —— .10 —— clams —— .05 —— *Schizophoria*

The lines are bonds of association at the levels of significance given by the numbers. Figure 7 shows graphically the number of occurrences of each member of the candidate pairs, and the relationships between total number of occurrences, number of occurrences together, and chi-square. In the first combination (*Linoproductus* and *Echinoconchus*), of the six sample units which contained *Echinoconchus*, five of them also contained *Linoproductus*, which itself occurred in only 14 of the 67 sample units. The likelihood of this distribution would be rather remote if their occurrence with respect to one another were random. Therefore, the value of chi-square is fairly high. Although there are only three sample units which contain both *Antiquatonia* and *Aviculopinna*, their bond of association is shown by chi-square to be significant at the .05 level. However, four occurrences of clams and *Lissochonetes* in the same sample units are of no significance because of the comparatively large number of units in which *Lissochonetes* occurs.

FIGURE 7

RELATIONSHIPS BETWEEN TAXA OF THE PAIRS TESTED BY CHI-SQUARE FOR POSITIVE ASSOCIATION

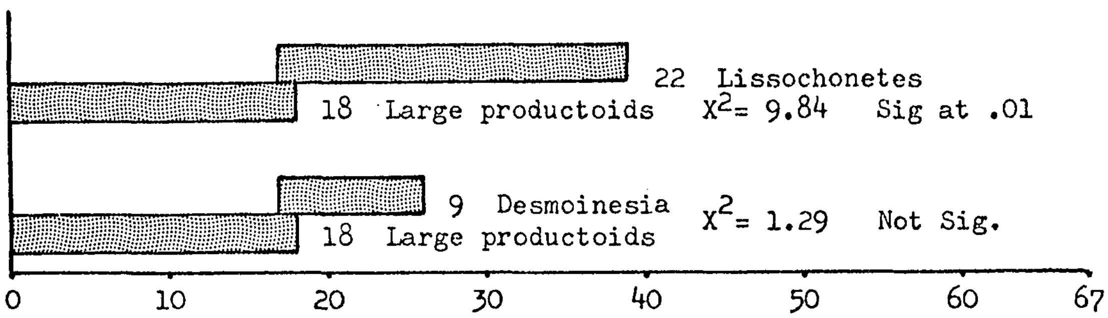


Inspection of the data revealed that at least two pairs of taxa seem to avoid one another, a phenomenon referred to by Johnson (1962) as negative association. Only one of these pairs (Lissochonetes and large productoids, Figure 8) occur together less frequently than would be expected by chance. The large productoids include Linoproductus, Antiquatonia, and Echinoconchus. Although the bond between Antiquatonia and Echinoconchus is rather weak (significant at the .10 level only), it is accepted here for two reasons. First, because of the considerable similarity of form and ancestry, it seems not unlikely that the three productoids had similar habitat requirements--much more so at least, than the clams and gastropods which showed about the same positive association. Second, their similarity of form and frequently poor preservation often made the distinction between these genera difficult.

The levels of significance used here are comparatively weak (Johnson, 1962, used the .005 level), but such statistical reassurances are not necessary when contemporaneity and proximity of specimens is more or less assured by the sampling plan. Unfortunately, this method of sampling yields a relatively small number of specimens, for it is tedious and time-consuming. Rocks which are abundantly fossiliferous, and would therefore yield a greater number of specimens for the collecting effort applied, would very likely be unsuitable for this method of sampling because the specimens would probably show no evidence of having been preserved in the same sediments in which they lived, and near the same animals which in life shared their environment.

FIGURE 8

RELATIONSHIPS BETWEEN TAXA OF THE PAIRS TESTED BY CHI-SQUARE FOR NEGATIVE ASSOCIATION



Number of Sample Lines

Fossil Density

Definition

Fossil density is the number of fossils per unit area of a synchronous surface. It is approximated here by the number of fossils occurring along a synchronous line of unit length--in this case, one meter.

Density and Grain Size

Each of the 67 sample lines was plotted (Figure 9) according to mean grain size and the number of fossils which occurred on each line. Above the median of the mean grain sizes (4.67ϕ), there are 148 specimens occurring on 34 sample lines. Below the median, there are 110 specimens on 33 sample lines. The number of specimens was weighted to offset whatever effect the small difference in the number of sample lines on either side of the median grain size might introduce. A chi-square test showed that the larger number of specimens occurring in the samples of greater than median grain size is significant at the .05 level. In other words, fossil density is greater in those sediments whose mean grain size is above the median of the grain sizes of the rocks which were sampled.

Density and Percentage of Grains

All the sample lines were replotted according to the percentage of grains and the number of fossils (Figure 10). Above the median percentage of grains (between 12% and 16%) 164 specimens occurred on

FIGURE 9
FOSSIL DENSITY AND GRAIN SIZE

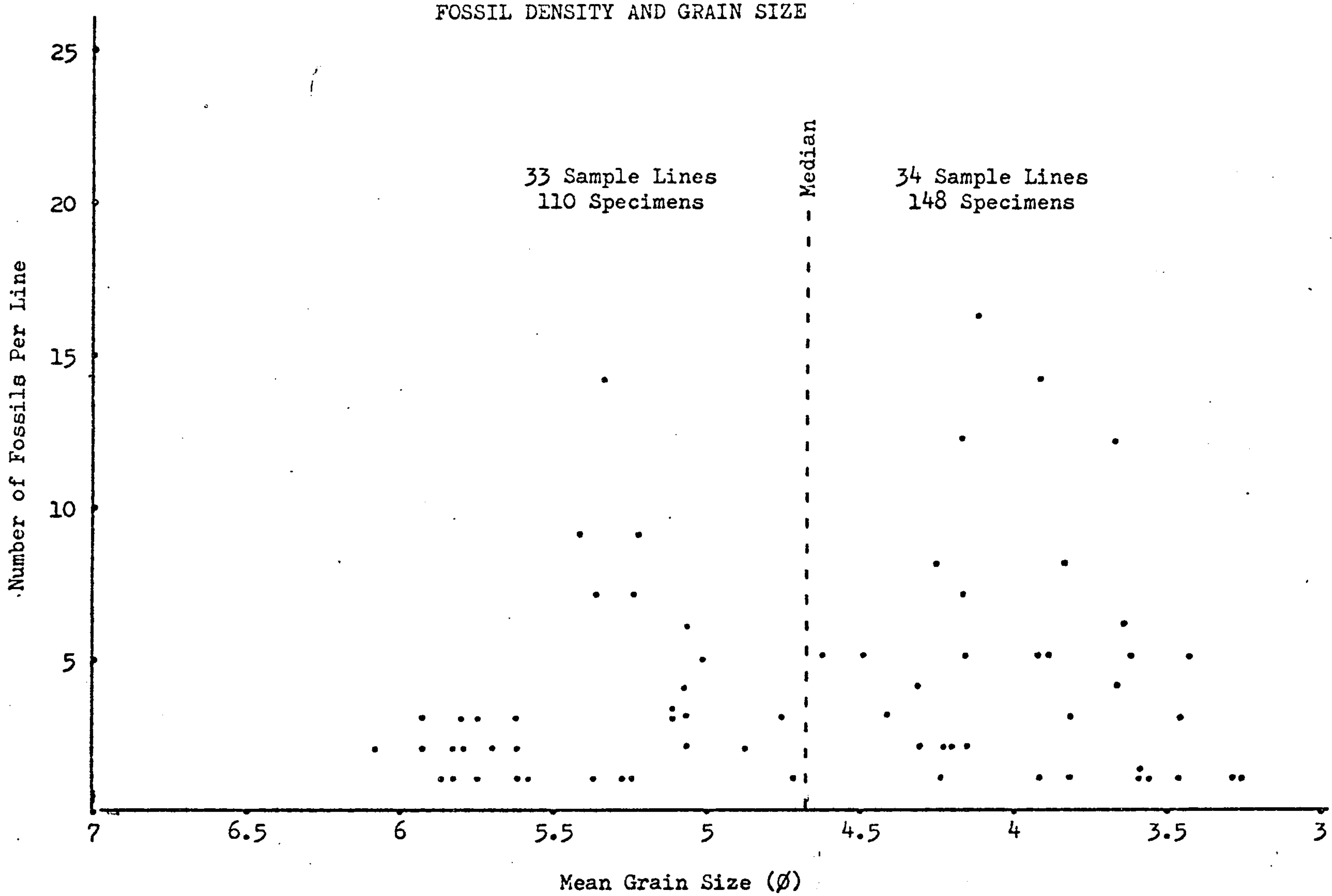
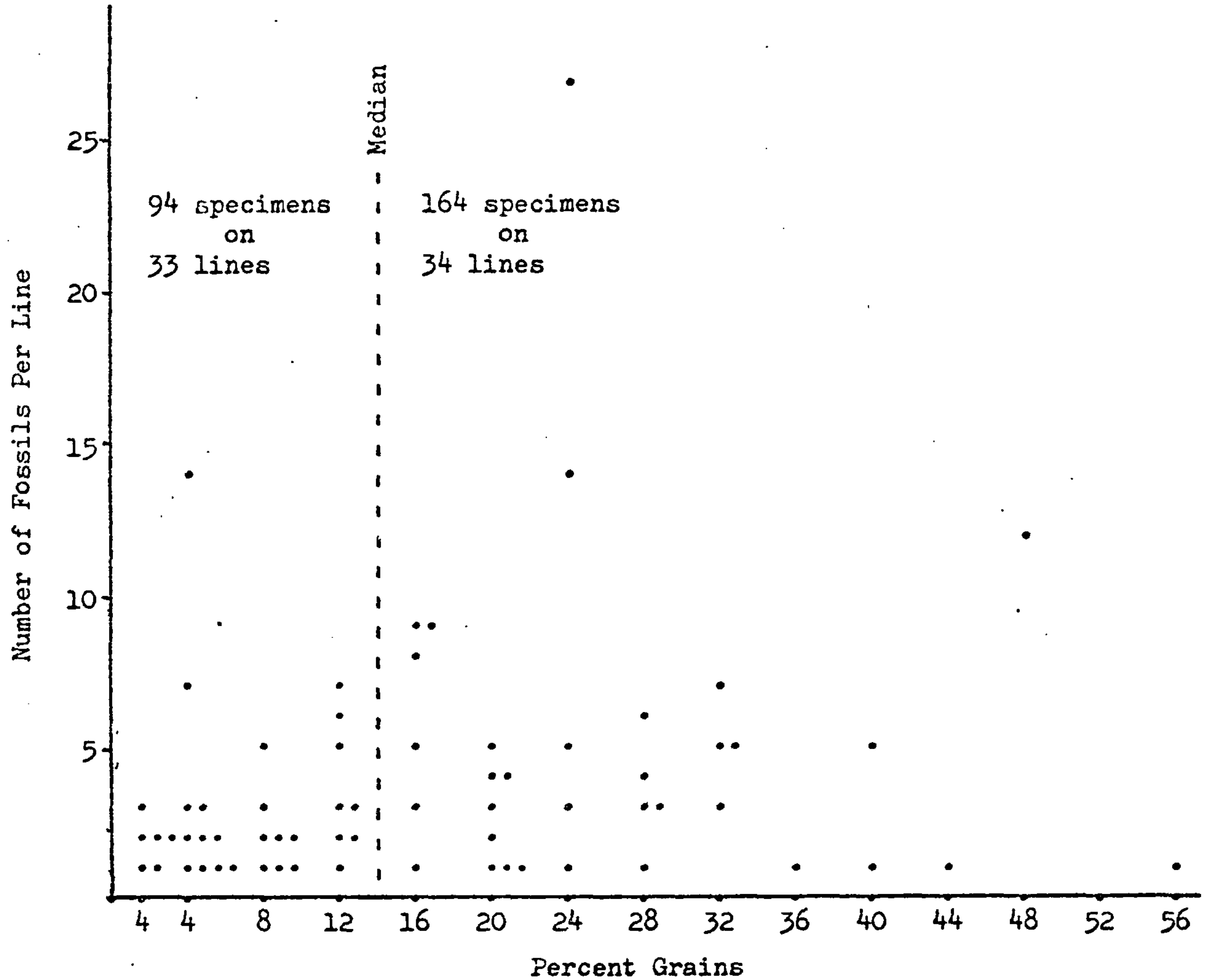


FIGURE 10

FOSSIL DENSITY AND PERCENTAGE OF GRAINS



34 sample lines, and below, 94 occurred on 33 lines. The number of specimens was weighted to compensate for the additional sample line which occurred above the median, and a chi-square test showed that the difference is significant at the .005 level. There are thus more fossils per sample line in those rocks which contain more than the median percentage of grains.

Density and Color

A plot of the samples according to fossil density by color category revealed no effect by color on density.

Density and Taxa Present

In order to determine whether the occurrence of a particular taxon is indicative of conditions which supported an unusually high or low density of preservable animals, the number of times each taxon occurred on lines with a given number of other specimens was recorded (Table VI). Only the large productoids and Dunbarella show any substantial degree of imbalance with respect to their occurrence on sample lines of greater or less than the approximate median density, and only Dunbarella shows a significant preference. All ten occurrences are on sample lines of less than median density, and the probability of this occurring by chance is .001 on the assumption that that genus is actually as likely to occur below the median as above. The probability rises to .002 if account is taken of the greater number of sample lines which occur below the approximate median.

TABLE VI

FOSSIL DENSITY OF SAMPLE LINES CONTAINING THE STUDY TAXA

	Number of Other Specimens, of any Taxon, on the Same Line											
	0	1	2	3	4	5	6	7	8	11	13	26
Dunbarella	3	6	1									
Aviculopinna	2		1	1	3						1	
Large productoids	3	2	2	2	1	1	2		1	1	2	1
Desmoinesia	2		2	1	2		1			1		
Lissochonetes	2	4	7	1	3	1	1	1	1	1		
Schizophoria	1		1		2	1				1		
gastropods	1	1	2		2			1				
clams		2	1		1	1				1		
Total	14	15	17	5	14	4	4	2	2	5	3	1

46 specimens | 40 specimens

Approximate Median

Numbers indicate number of sample lines

Grain Size and Percentage and Occurrence of Taxa

Separate plots of the occurrence of each fossil taxon on the grain size-grain percentage diagram (Figure 3) showed a non-random distribution of points, i.e., certain fossils tend to be restricted to certain areas of the chart. The distribution plots are summarized in Table VII, which also shows the probability associated with each distribution. *Dunbarella* and *Lissochonetes* have a strong tendency to occur in rocks with an average grain size below the median, whereas *Aviculopinna*, large productoids, and *Schizophoria* tend to occur in rocks with an average grain size above the median. Clams show the same tendency, but as "clams" is really a broad taxon, including animals which are known to have quite different habitat requirements, the tendency is a reflection of the kinds of clams encountered, but is, nevertheless, a sample of the general habits of Pottsville clams in the study area. The same might be said for the gastropod taxon, for inspection of the plotted points shows that the two occurrences below the median grain size are actually borderline cases, and gastropods do seem to have avoided the finer grain sizes. Therefore, however wide the habitat requirements of gastropods may be, those encountered show a definite tendency to occur in the coarse range of grain sizes.

With respect to the percentage of grains, *Dunbarella* occurs below the median, whereas *Aviculopinna*, *Desmoinesia*, and *Schizophoria* tend to occur above.

Table VIII summarizes the occurrences of all the fossil taxa

TABLE VII

FOSSIL OCCURRENCE AND GRAIN SIZE AND PERCENTAGE

Fossil Category	Grain Size: No. of Sample Lines Above Mdn	Grain Size: No. of Sample Lines Below Mdn	P*	Percent Grains: No. of Sample Lines Above Mdn	Percent Grains: No. of Sample Lines Below Mdn	P*
Dunbarella	1	9	.011	0	10	.001
Aviculopinna	7	1	.035	7	1	.035
Large productoids	13	5	.048	9	9	.593
Desmoinesia	6	3	.254	8	1	.020
Lissochonetes	5	17	.008	11	11	.584
Schizophoria	6	0	.016	6	0	.016
gastropods	5	2	.227	3	4	.500
clams	5	1	.109	3	3	.656

*P = the probability of there being the observed on some greater imbalance between the number of occurrences above and below the median by chance alone.

TABLE VIII

GRAIN SIZE AND PERCENTAGE PREFERENCES SHOWN BY THE STUDY TAXA

		Percent Grains		
		Above Median	No Preference	Below Median
Grain Size	Above Median	Aviculopinna(.035) (.035) Schizophoria(.016) (.016)	gastropods*	
	No Prefer-ence	Desmoinesia (.02)	clams (.109) Large productoids	
	Below Median		Lissochonetes(.005)	Dunbarella(.02) (.001)

Numbers below names are significance levels with respect to o/o quartz

Numbers after names are significance levels with respect to grain size

*Significance level only .23, but the two occurrences below the median grain size are actually borderline, and there are no occurrences clearly below the median with respect to the grain size and grain percentage of the sediments in which they were found.

Color and Occurrence of Taxa

The comparatively small number of fossil occurrences in each of the five color categories made it necessary to lump them into two, pure gray and yellowish.

The number of occurrences of each fossil taxon in each color category is shown in Table IX. The cumulative binomial distribution shows that, after weighting for the larger number of yellow than gray samples, the large productoids occur sufficiently more often in the yellow category than in the gray that the probability of this being due to chance variation is .004. The preferences shown by *Lissochonetes*, *Schizophoria*, gastropods, and clams for the gray category are not quite so strong, being .076, .063, .035, and .063 respectively.

TABLE IX

OCCURRENCE OF THE STUDY TAXA WITH RESPECT TO COLOR OF THE POWDERED SEDIMENT

	Unweighted		Weighted		
	Yellow Tints	Pure Gray	Yellow Tints	Pure Gray	Significant Preference
Dunbarella	7	3	7	3.5	None
Aviculopinna	4	4	4	4.67	None
Large productoids	15	3	15	3.5	Yellow
Desmoinesia	3	6	3	7	None
Lissochonetes	8	14	8	16.34	Gray
Schizophoria	1	5	1	5.83	Gray
Gastropods	1	6	1	7	Gray
Clams	1	5	1	6	Gray

SUMMARY OF RESULTS

1. Fossils occur in rocks of restricted mean grain size, from very fine sand to fine silt.

2. Fossil density is greater in sediments whose mean grain size ranges from very fine sand to the middle of coarse silt. Density is less in sediments whose mean grain size ranges from the middle of coarse silt to fine silt.

3. Fossil density is greater in sediments with more than the median percentage (14%) of grains, although they occur in sediments whose grain percentage ranges from 56% to less than 4%.

4. Fossil density does not vary with the color of the powdered sediment, which is a reflection of the relative amounts of siderite, pyrite, and organic matter present.

5. Fossil density is low wherever *Dunbarella* is present.

6. Some taxa had sufficiently similar habitat requirements that they occur together in the same sample line more often than would be expected by chance. These significant associations are:

Linoproductus

.01 / \ .01

Echinoconchus —.10— *Antiquatonia* —.05— *Aviculopinna*

clams —.05— *Schizophoria*

7. *Lissochonetes* and large productoids have sufficiently different

habitat requirements that they occur together with less frequency than would be expected by chance (negative association).

8. *Aviculopinna*, *Schizophoria*, and *Desmoinesia* occur more often in rocks with a comparatively high grain percentage (greater than 14%), while *Dunbarella* prefers rocks with less than the median grain percentage.

9. *Aviculopinna*, *Schizophoria*, clams, and gastropods occur more often in rocks with a mean grain size above the median. *Lissochonetes* and *Dunbarella* prefer grain sizes below the median.

10. With respect to color of the powdered sediment, large productoids occur more often in the yellow categories. *Lissochonetes*, *Schizophoria*, clams, and gastropods show a preference for pure gray.

CONCLUSIONS

Within the boundaries imposed by the Kanawhan sedimentary regime in the Black Warrior Basin, maximum but not minimum grain size seems to have been a limiting factor in the distribution of faunas. Coarse-grained sediments (greater than very fine sand) were probably deposited on beaches or in streams, neither of which generally carries a large preservable fauna. Fine-grained sediments with a mean grain size as low as about 6ϕ (medium to fine silt), contain appreciable quantities of fossils, and no finer sediments occur in the basin in any abundance.

The coarser fossiliferous rocks contain fossils in greater density. Speculation as to the reason for this yields one possibility. Most of the animals involved were filter feeders. A body of water with very little movement in it (and therefore one which was the site of deposition of a very fine-grained substrate) would not support a very dense population of such animals because they would very quickly exhaust the nutrient supply suspended in the water about them. Enough current to effect an adequate resupply might also be expected to cause an increase in the size of the particles which were being deposited. Although the physical characteristics of a substrate of very fine particles may have been unsuitable to many taxa, they may not in themselves have affected the numbers of individuals of the taxa which found it suitable.

The effect of grain size and grain quantity on fossil density

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The effect of grain size and grain quantity on fossil density seems also to be expressed in indirect ways, for example, the presence of Dunbarella indicates that fossil density will be below the median. Dunbarella distinctly prefers substrates consisting of grains of less than the median size, and in less than the median quantity. These preferences reflect the amount of energy available--in the waters in which the animals lived--for the transportation of sedimentary particles. Dunbarella apparently inhabited waters with less current than any of the other animals encountered. Furthermore, agitation of the bottoms on which Dunbarella lived seems unlikely, for the fine material that composed the substrate, if brought into suspension near the bottom, would probably have created an intolerable condition for a suspension feeder. But for life on a quiet, fine-grained substrate, Dunbarella seems admirably adapted. Its wafer-like shape would minimize the difficulty of sinking into the soft bottom, and if conditions at a particular resting place became unsuitable because of turbidity of the bottom or depletion of nutrients, or of oxygen, the animal may well have had the capability of swimming to another spot, as can some of the modern pectenaceans. If Dunbarella is stenohaline marine like many modern pectenaceans, it must have lived in waters below normal wave base, but there is no evidence to indicate that that is the case. It seems more likely that it lived in small bodies of water which were too small or too protected to have waves of any magnitude, and which were not the site of deposition of relatively coarse materials from streams. Small brackish or even fresh water lakes or the drowned streams which entered them seem to be the most likely habitat for these animals. The modern bay scallop, the euryhaline species Aequipecten irradians, lives in similar bay and estuary habitats, but generally on sandy substrates (Ladd et al., 1957, p. 630).

The occurrence of Aviculopinna and Schizophoria seems to have been directly and closely controlled by the grain size and grain percentage of the substrate. Both genera almost certainly inhabited shallow marine waters that bordered the coastal plain. No nonmarine brachiopods are known, and there is no reason to suppose that Schizophoria is an exception. Recent Pinnidae are marine, and more stenohaline than many other pelecypods (Abbott, 1954). The Paleozoic forms probably had the same requirements. When compared to all the substrates sampled, those preferred by Schizophoria and Aviculopinna are coarse grained and clean, but they are nevertheless of fine texture and contain a large proportion of matrix, largely fine micas and clay. Currents were strong (relative to those affecting the other fossiliferous sediments) and there was no doubt some agitation due to waves, but the combined effect of these was not enough to result in a very clean substrate--at least within the span of time between the introduction of the detritus and its burial.

Clams and gastropods have the same preference for a coarser grained substrate as Aviculopinna and Schizophoria, but they show no apparent preference for sediments with more or less than the median percentage of grains. To draw conclusions about the habitat preferences for all clams and all gastropods would, of course, be entirely unjustified; and conclusions about the particular sets of genera which comprise the "clam" and "gastropod" taxa might not apply to any one genus of the group. The preference of clams and gastropods for coarser grained substrates is meaningful only for the grouped genera, and then only when the occurrence of those genera is in the same proportion. This is clearly a severe limitation. A tentative hypothesis to be confirmed or rejected by future studies is that certain of the clams and gastropods were burrowers which required a substrate made friable by coarser grains, regardless of the quantity of such grains present. The widely explanate apertural margins of some bellerophontaceans (three of which make up part of the gastropod taxon) may have functional significance in this respect. It seems likely that these animals carried the aperture over their heads, or at least, anteriorly (Knight, et al., 1960, p. I173). If the inner surface of the "bell" rested on the dorsal surface of the body mass of a snail which was very large for the size of its shell, then it may have had no functional advantage. Such a discrepancy in the size of the shell as compared to the size of the animal might account for the fact that no opercula are known for this group. The body would have been much too large to be withdrawn into the shell. If, on the other hand, the body mass was in more common proportion to the size of the shell, then the flared apertural margins must have extended out, wing-like, on either side of the animal--an awkward and unlikely sort of arrangement if the shell was carried above the substrate. Such wings would be useful in providing stability on a soft bottom with which they came in contact, but this would put the body mass beneath the surface of the substrate, which, in fact, may have been the mode of life favored by these organisms. The position of the selenizone indicates that discharge of waste was very likely directly upward, which would be a desirable arrangement for an infaunal animal. Food could have been procured from the sediment in which the animal buried itself, or in the manner of Aporrhais (Purdy, 1964) which draws water in through a small hole in the sediment. Unfortunately, the clams offer no features which bear on the question of whether or not they were burrowers.

Though Lissochonetes and Desmoinesia occur together in moderate abundance at at least one locality (Locality 5, The Wye), they do not form a significant positive association. The environmental requirements of the two obviously overlap, but do not correspond completely. The environment at The Wye was one which happened to satisfy the requirements of both genera. The maximum amount of water current was never very high, as is evidenced by the small grain size, below the median for all samples. This condition (or some unknown but attendant condition) was preferred by Lissochonetes and was either tolerated by or of no consequence to Desmoinesia. If the percentage of grains can be interpreted as a relative measure of water movement, then Desmoinesia can be said to prefer that the maximum current velocity be comparatively frequent or persistent (although not necessarily strong), or that there be enough winnowing to remove some of the finer material. Of the seven sample units at The Wye, three showed a comparatively high percentage of grains, and thereby indicate an environment preferred by Desmoinesia, and either tolerated by or of no consequence to Lissochonetes.

The growth position of Lissochonetes is uncertain. Most specimens were found lying parallel to bedding, with the concave brachial valve down, and the convex pedicle valve up, the attitude the shells would have assumed if they had been washed about by currents or wave agitation. It is not a likely growth position, because the line of commissure would have been on the substrate. However, the shells of Lissochonetes occur in fine-grained sediments inferred to have been deposited in habitats having water movement too weak to overturn shells of this size. Furthermore, had water movement been sufficient to overturn the shells, the incidence of separated valves would have been much higher; marginal spines would not be found intact; and the shells would probably have been concentrated.

It has been postulated that some brachiopods lived off the substrate,attached to plant stems, or perhaps to floating plants (Rudwick, 1965, pp. 201 and 211). If this was the mode of life of Lissochonetes, it does not explain why the shells are found with the pedicle valve uppermost, for if the shell of Lissochonetes is dropped through a cylinder of water, it will land on the bottom with the convex side down. (About 15 repetitions of this experiment all yielded the same result.) In the absence of wave agitation or current velocity to turn each shell into the position which is hydrodynamically most stable (convex pedicle valve uppermost), any postulated growth position must be one which would ultimately result in the shell settling into that position. The shells may have been turned over by other, unpreserved organisms, but that they should turn almost all the shells into the same position seems unlikely.

Lissochonetes must have been attached to or imbedded in the substrate. Otherwise the brachial valve or the pedicle valve would have to be against the substrate, positions which would either effectively prevent feeding and water circulation or require overturning. The shape and symmetry of Lissochonetes, if the animal was benthonic, require that the hinge line be maintained parallel to the substrate and closer to it than the anterior edge of the shell. In addition it must have been so situated that it would ultimately settle into the position in which the shells are presently found, i.e., pedicle valve uppermost. A range of positions from subvertical to nearly horizontal, the brachial valve being nearer to the substrate in any case, is possible. The marginal spines would have extended into the substrate to assist in holding the shell in what would otherwise be a very unstable position. If the angle between the brachial valve and the substrate was near ninety degrees, the marginal spines would be securely imbedded, but the shell would offer maximum resistance to whatever minor currents may have been present. If the angle between the brachial valve and the substrate was small, the shell would offer less resistance to water movement and would be less subject to any sort of mechanical disturbance, but the spines would not be as firmly imbedded. Some intermediate angle, probably about forty-five degrees, seems the best compromise. A shell in that position would have the line of commissure well above the substrate, and if it eventually settled down before burial, it would then be preserved with the pedicle valve up. If it did not settle before burial, it would still be rotated to a horizontal or near-horizontal position as the sediment was compacted and dehydrated. A few specimens were collected which were folded parallel to the hinge line, the posterior part of the shell being more or less perpendicular to bedding, the anterior part more or less parallel to bedding. In retrospect, these might be specimens which lived and were buried in a nearly vertical position, then were folded during the process of sediment compaction.

The negative association of Lissochonetes and large productoids does not appear to be due to different requirements of size and percentage of grains nor to the predominantly physical factors of the environment which would produce such differences. The habitat requirements of these two groups might differ with respect to either biological or chemical conditions. In the case of a bottom densely populated with large productoids (e.g., samples 033, 035, 036, 061, and others) they, being the dominants, may have produced conditions by their physical presence and by their life processes which were not suitable for the growth of Lissochonetes. But large productoids do not always occur in such great numbers, so some other factor or factors must have been involved. Some insight into the chemistry of the environments preferred by these two taxa can be gained from the color of the sediment (when powdered) in which they lived. Lissochonetes shows a preference for those sediments with a pure gray color (low Eh), and the large productoids show a strong preference for those which have a yellow tint (high Eh). The productoids perhaps required or preferred a higher oxygen content in the waters in which they lived than did Lissochonetes, perhaps simply because of their larger size and greater density. However, the variations of Eh (and pH) which determined which of the color-producing minerals would precipitate may have been characteristic of the water below the sedimentary interface rather than that used by the brachiopods.

Linoproductus, Antiquatonia, and Echinoconchus apparently have quite similar habitat requirements. The comparatively low significance of the bond of association between Echinoconchus and Antiquatonia suggests that although the ecologic spheres of these organisms overlapped, they were not so nearly coincident as those of Antiquatonia and Linoproductus or Linoproductus and Echinoconchus. This supposition receives some support from the Aviculopinna-Antiquatonia association, since Aviculopinna shows no tendency to occur with the other two productoids.

The relationships which have been shown to exist between fossil variables and between sediment and fossil variables do not necessarily apply to the same taxa outside the Black Warrior Basin. The entire range of substrate types which are suitable for a given taxon simply may not be present in the basin. As range zones are determined from all local range zones, so must the range of acceptable variation in a given environmental factor be determined from detailed local studies.

Rather than a survey such as this, future studies would be more profitable if centered about a particular taxon, and extended into as large a variety of sedimentary environments as possible. Sampling could be conducted in much the same way as here, but modified to the extent that each sample unit contain at least one specimen of the taxon under study. This would not only provide a much greater volume of data for the selected taxon than was collected for any in this study, but it would permit conclusions relevant to morphological change in response to environment, geography, and time (if sufficient stratigraphic control were included).

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EXPLANATION OF PLATES

Only those taxa which were encountered during sampling are illustrated. Specimens with six-digit numbers were collected as part of the sampling program. The first two digits indicate the locality number (Table V); the second two the sample line number; the last two the centimeter point at which the fossil intersected the sample line. Specimens with one and two-digit numbers were not collected as part of the sampling program, but were selected for illustration because of their better preservation.

PLATE I

Figures

1 -- <u>Edmondia</u> ? sp. (x2)

Right valve of cast, Locality 9, specimen 090850

2 -- <u>Edmondia</u> ? sp. (x1)

Right valve of flattened cast, Locality 2, specimen 021050

3,4 -- <u>Aviculopinna</u> sp. (x1)

3, Left valve; 4, ventral view; Locality 7, specimen 070650

5 -- <u>Dunbarella</u> sp. (x1)

Cast of left valve, from strip mine by Price Bridge, Sec. 22, T. 16 S., R. 7 W., Walker Co., Ala., specimen 1

6 -- <u>Bellerophon</u> sp. (x1)

Abapertural view of internal mold with some shell material remaining, Locality 1, specimen 2

7,8 -- <u>Euphemites</u> sp. (x2)

7, Anterior view; 8, apertural view; Locality 4, specimen 3

9,10 -- <u>Trepospira</u> sp. (x2)

9, Apical view; 10, apertural view; Locality 1, specimen 010460

11,12 -- <u>Ianthinopsis</u> sp. (x2)

11, Apertural view; 12, side view; Locality 1, specimen 010267

13 -- <u>Michelinoceras</u> s.l. sp. (x2)

Side view, Locality 1, specimen 4

PLATE I (continued)

Figure

14,15 -- Worthenia sp. (x3)

14, Apical view; 15, side view; Locality 1, specimen 010450

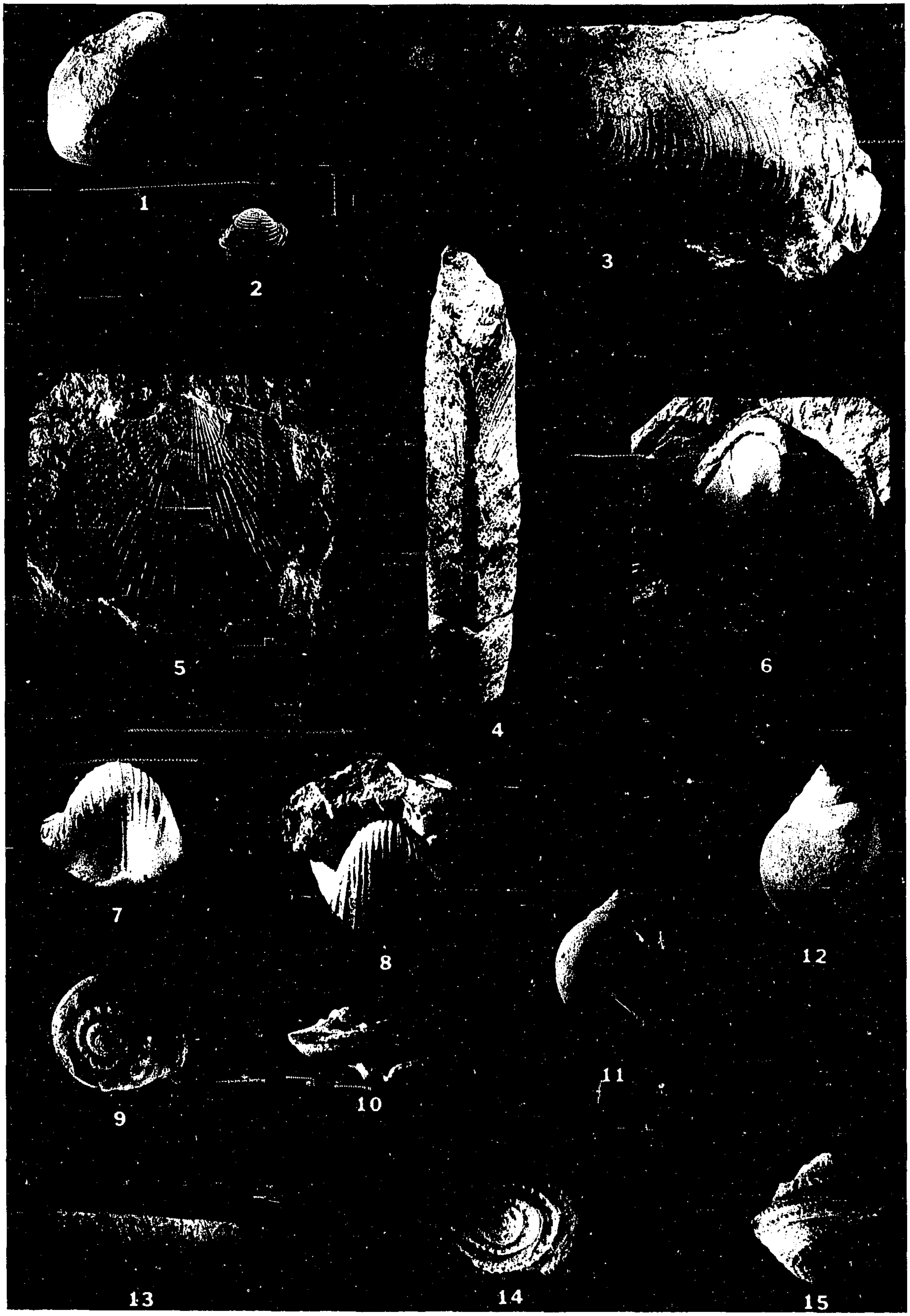

PLATE I

PLATE II

Figures

1,2,3 -- Echinoconchus sp. (x2)

1, Cast of pedicle valve exterior; 2, mold of brachial valve interior; 3, mold of brachial valve exterior; Locality 6, specimen 060226

4,5 -- Linoproductus sp. (x2)

4, Ventral view; 5, dorsal view; Locality 2, specimen 5

6,7 -- Linoproductus sp. (x2)

6, Ventral view; 7, side view; Locality 6, specimen 6

8,9 -- Antiquatonia sp. (x2)

8, Ventral view; 9, anterior view; Locality 2, specimen 020171

10 -- Desmoinesia sp. (x2 1/2)

Brachial interior, Locality 1, specimen 7

11 -- Desmoinesia sp. (x2)

Pedicle interior, from strip mine by Price Bridge, Sec. 22, T. 16 S., R. 7 W., Walker Co., Ala., specimen 8

12 -- Desmoinesia sp. (x2)

Ventral view, from strip mine by Price Bridge, Sec. 22, T. 16 S., R. 7 W., Walker Co., Ala., specimen 9

13 -- Desmoinesia sp. (x2 1/2)

Ventral view; shell material absent anteriorly so that mold of ridge around interior of pedicle valve is visible; Locality 3, specimen 10

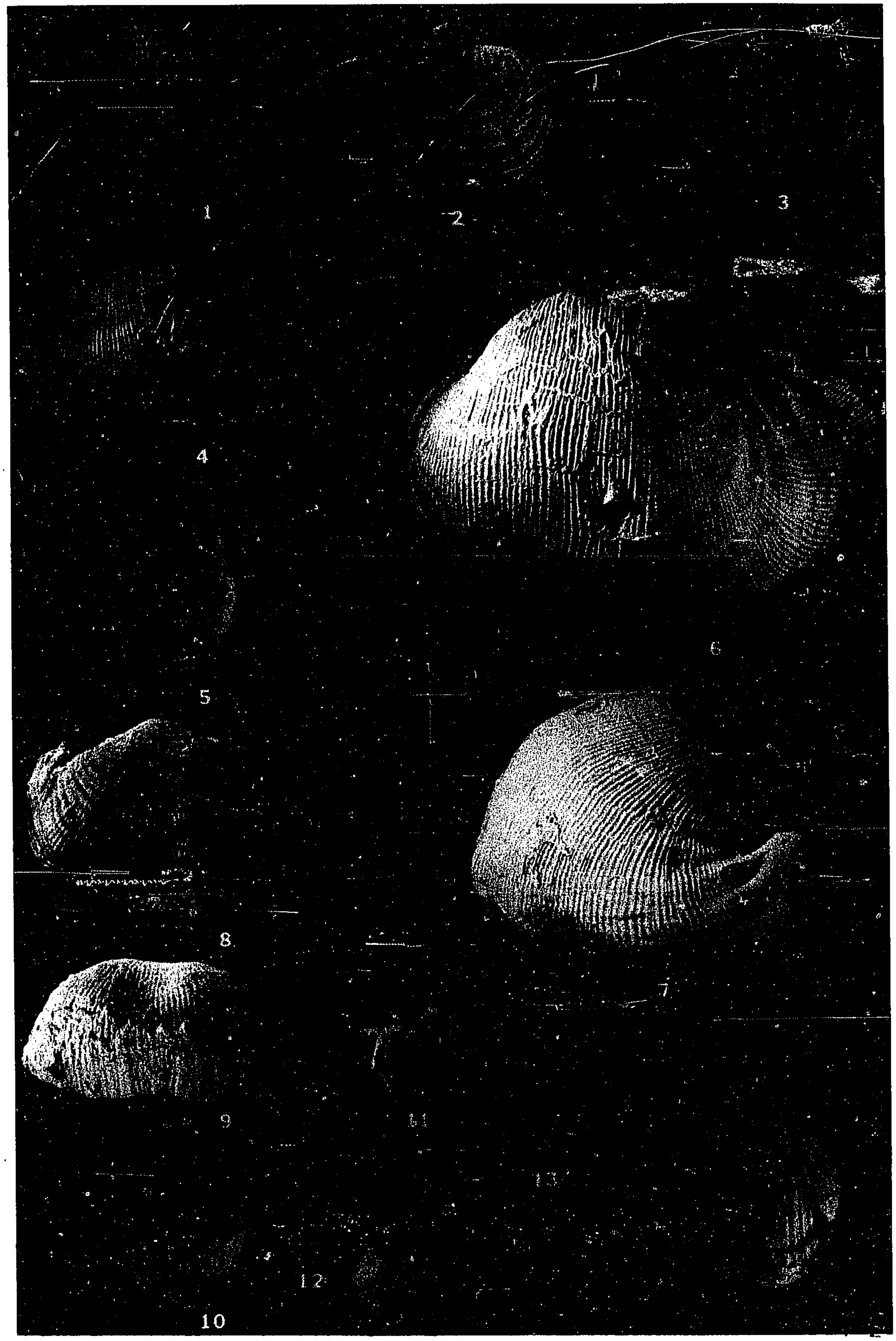

PLATE II

PLATE III

Figures

1 -- <u>Lissochonetes</u> sp. (x4)

Pedicle exterior, Locality 5, specimen 11

2 -- <u>Lissochonetes</u> sp. (x4)

Pedicle exterior, from strip mine by Price Bridge, Sec. 22 T. 16 S., R. 7 W., Walker Co., Ala., specimen 12

3 -- <u>Lissochonetes</u> sp. (x4)

Brachial interior, Locality 4, specimen 13

4 -- <u>Lissochonetes</u> sp. (x4)

Brachial interior, Locality 4, specimen 14

5,6 -- <u>Lissochonetes</u> sp. (x4)

5, Pedicle interior; 6, mold of pedicle interior; well-developed vascular trunks as in <u>Neochonetes</u> are visible, but exteriors are smooth, non-capillate, as in Figure 1; Locality 1, specimen 15.

7 -- <u>Lissochonetes</u> sp. (x4)

Mold of pedicle interior, with some of the shell material still present, Locality 4, specimen 16

8 -- <u>Schizophoria</u> sp. (x1 1/2)

Pedicle exterior, Locality 1, specimen 17

9 -- Spiriferidina, genus and species indeterminate (x1 1/2)

Pedicle valve, Locality 1, specimen 18

PLATE III (continued)

Figures

10 -- Spiriferidina, genus and species indeterminate (x1 1/2)

Pedicle valve, Locality 1, specimen 19

11 -- <u>Derbyia</u> sp. (x1 1/2)

Pedicle exterior, Locality 7, specimen 070497

12,13 -- <u>Orbiculoidea</u> sp. (x1 1/2)

12, Apical view, pedicle valve exterior; 13, side view; pedicle valve exterior; Locality 10, specimen 100150

14 -- <u>Orbiculoidea</u> sp. (x1 1/2)

Brachial valve exterior, from road cut approximately 1/4 mile west of Locality 7, specimen 20

15,16 -- Rugosa, genus and species indeterminate (x2)

Alar view and transverse section, Locality 2, specimen 020410

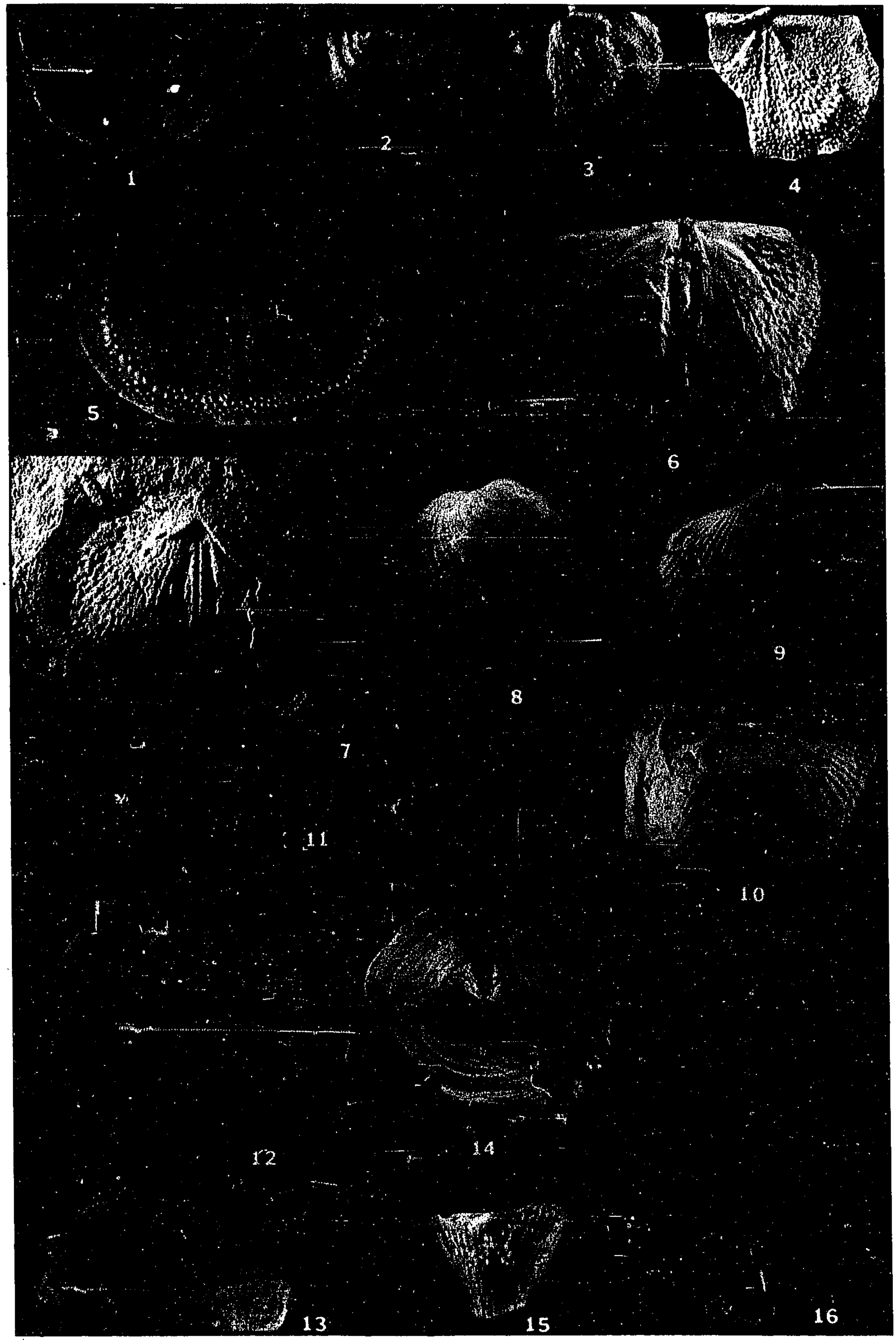

PLATE III

VITA

James Walker McKee was born on September 25, 1932, in Lawrenceburg, Kentucky. After graduation from high school there in 1950, he attended Marion Military Institute (1950-1952), and the University of Rhode Island (1953-1954), before entering Louisiana State University (1958), from which he received the B.S. degree in 1960 and the M.S. in 1964. When not in school, he has been employed as a distillery worker, salesman, and sea sampler, and has completed two tours of duty with the U. S. Army. While at L.S.U., McKee was a graduate teaching assistant, and the recipient of fellowships sponsored by the Pan American Petroleum Corporation and the Socony Mobil Oil Company. He is presently Instructor of Geology at Wisconsin State University in Oshkosh.

His wife is the former Macey Edwards Blackburn of Versailles, Kentucky. They are the parents of three children.

EXAMINATION AND THESIS REPORT

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Title of Thesis: Relationships in Part of the Black Warrior Basin of Alabama

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Date of Examination:

August 12, 1966